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August 28, 1998

Office of Naval Research
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Arlington, VA 22217-5660

RE: Annual Performance (Technical) Report for Grant Number:
N00014-96-1-1227 Dr. Masamichi Inoue

Dear Ms. Oliver:

Enclosed is the Interim Progress Report (original + 2 copies) for the above-referenced Louisiana DEPSCoR project. We are excited about the accomplishments we are making as a result of the agreements between the Board of Regents and the Office of Naval Research under DEPSCoR. Your continued support of this project is appreciated.

If you have any questions or need additional information, please do not hesitate to contact Mr. Jim Gershey, Director of Program Evaluation, or me at 504-342-4253.

Sincerely,

Kerry Davidson (jsq)

Kerry Davidson
Deputy Commissioner for Sponsored Programs

Enclosure

c: Office of Naval Research Regional Office, Atlanta (w/one copy of report)
Director, Naval Research Laboratory (w/one copy of report)
Defense Technical Information Center (w/two copies of report)
Dr. Masamichi Inoue (letter only)
Mr. Jim Gershey

19980903 009

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
August 15, 1998

3. REPORT TYPE AND DATES COVERED
Annual Report (8/31/97-8/30/98)

4. TITLE AND SUBTITLE
Observation and Modeling -- An Integrated Study of Transport through the Strait of Bab al Mandab Task B: Modeling

5. FUNDING NUMBERS
C: DOD/LEQSF(1996-99)-02
G: ONR N00014-96-1-1227

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DOD/Board of Regents
150 Third Street,Suite 129
Baton Rouge, Louisiana 70801-1389

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12 b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A new bottom bathymetric data set with a resolution of 500 m was created based on the digitization of the nautical charts. A new curvilinear coordinate model grid was generated based on the digitized bathymetric data. The Princeton Ocean Model was configured to use the model grid with two open boundaries located along the northern boundary located in the Red Sea and the southern boundary located in the Gulf of Aden. Relaxation experiments were carried out, whereby the model stratification was initially set to some realistic stratification, and the model was then allowed to develop its own dynamics while applying the radiation open boundary conditions and relaxing the temperature and salinity values along the two open boundaries toward the initial boundary conditions. Summer and winter stratification profiles from Levitus climatology as well as the CTD data collected under Task A were used. The model develops a distinct two-layer flow in the winter stratification, while a three-layer flow would result in the summer stratification as observed previously. One prominent feature identified in the model is the time-dependent nature of the flow with energetic oscillations with periods of 12~15 days especiallly in summer, similar to what has been noted during the field experiemnts under Task A.

14. SUBJECT TERMS
Red Sea, Strait of Bab al Mandab, Modeling strait flow

15. NUMBER IF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Task B: Modeling

In order to resolve important hydrodynamic features at the Strait of Bab al Mandab, ETOP05 world topography data with its 1/12 degree resolution was judged to be too coarse to use for setting up the model domain. In order to obtain more detailed topographic data, the nautical charts published by Defense Mapping Agency (available from NOAA National Ocean Service) was digitized. The digitized bathymetric data cover the area extending from 11.3° to 14.4°N and from 41.7° to 45°E with a resolution of 500m. Comparison of the digitized data to the bottom profiles measured during the cruises under Task A confirmed the accuracy of the digitization.

Upon testing various model grid configurations, a new curvilinear coordinate grid was generated based on the digitized bathymetric data. The new model dimensions used are 180 by 70 by 11 (for the vertical). The resulting minimum grid size is 345 m in x-direction and 641 m in y-direction located near the narrowest constriction in the strait, and the maximum grid size is 3.952 km in x-direction and 2.634 km in y-direction located near the northern and the southern open boundaries.

The Princeton Ocean Model (POM) was configured to use the model grid with two open boundaries located along the northern boundary located in the Red Sea and the southern boundary located in the Gulf of Aden. Radiation open boundary conditions were used for velocities at the open boundaries, while temperature and salinity in inflow along the open boundaries were relaxed toward the initial boundary conditions, i. e., typical hydrographic conditions in the Red Sea and Gulf of Aden. All the experiments run so far are "relaxation experiment" whereby the model stratification was initially set to some realistic stratification, and the model was then allowed to develop its own dynamics while applying the radiation open boundary conditions and relaxing the temperature and salinity values along the two open boundaries toward the initial boundary conditions. Those experiments were run so far without the impact of wind forcing.

Initially, the summer and winter stratification from Levitus seasonal hydrographic data were used to initialize the model. Typically, during relaxation, the model would develop a distinct two-layer flow in the winter stratification, while a three-layer flow would result in the summer stratification as observed previously. One prominent feature identified in the model is the time-dependent nature of the flow even after a long time integration (e. g., 200 days). Those time-dependent motions appear to be associated with active eddy shedding in the inflow as well as outflow at the strait. In particular in the summer stratification, energetic peaks of approximately 14 days are observed. Those energetic motions are most prominent near the narrowest constriction of the strait.

Similar "relaxation experiment" was conducted using the CTD data collected during the summer and winter cruises under Task A. In doing so, the Levitus climatology was used below 350 m because the CTD data were collected only down to that depth. In comparison to the Levitus climatology, the advantage of using the CTD data was the ability to resolve much more

details in the fine-scale structure in the T- and S-profiles in the top 350m. The resulting flow patterns which develop in the model are basically similar to what was observed for the Levitus climatology, i. e., a two-layer flow in the winter and a three-layer flow in the summer. However, there were notable differences in detail, e. g., the salty bottom outflow from the Red Sea is much saltier in this case while it is much more diluted in the Levitus climatology. Again, strong time-dependent nature of the flow is evident especially in the summer with most energetic motions are found for the periods of 12~15 days. Comparing the two seasons, the winter condition appears to settle down to more quiet "steady-state" while the summer condition appears to result in more energetic "steady-state" even after 100 days, i. e., a fresher water tongue originating from the Gulf of Aden and penetrating northward into the Red Sea at an intermediate depth never reaches a steady-state (moving at a quasi-steady speed) (a feature recently observed by Smeed (1997)), instead, time-dependent back-and-forth oscillations are superimposed on top of its general northward movement. Currently, details of those time-dependent flow patterns are being examined including a comparison to observations. Interestingly, energetic motions of periods around 10 days had been observed during the field experiments under Task A.

In the third year, we plan to examine; 1) the effect of the model domain size and model grid resolution; 2) the impact of various model parameters including the formulations of viscosity and diffusivities; 3) the impact of wind forcing. In addition, tide experiments would be carried out, whereby tides of realistic amplitudes will be imposed at both ends of the model domain to represent tides coming in from the Red Sea and the Gulf of Aden. One of the exciting findings of the field program under Task A is the discovery of rapid response of the throughflow transport at the strait to barotropic pressure gradient setup by abrupt wind changes. Additional experiments are being planned to study this phenomenon.